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FEDERAL COMMUNICATIONS COMMISSION
OFFICE OF SECRETARY

January 30, 1995

Federal Communications Commission
Secretary's Office
1919 M Street, N.W.
Room 222
Washington, D.C. 20554

94-124

Re: Amendment of Parts 2 and 15 of
the Commission's Rules to Permit
Use of Radio Frequencies Above 40 GHz
for New Radio Applications
Docket No. ~~944~~-124
RM-83-9

To Whom It May Concern:

On behalf of Honda R&D Ltd. and Honda R&D North America, Inc. (hereafter, Honda), American Honda Motor Company, Inc. submits the enclosed comments to the FCC Docket referenced above. Honda appreciates this opportunity to comment on this important issue.

If you have any questions on these comments, please contact the undersigned at (202) 554-1650.

Sincerely,

Eiji Amito

Mr. Eiji Amito
Senior Vice President

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FEDERAL COMMUNICATIONS COMMISSION
OFFICE OF SECRETARY

Before the
FEDERAL COMMUNICATIONS COMMISSION
Washington, D.C. 20554

In the matter of	)	
Amendment of Parts 2 and 15	)	
of the Commission's Rules to Permit	)	ET Docket No. 944-124
Use of Radio Frequencies Above 40 GHz	)	RM-83-9
for New Radio Applications	)	

COMMENT FOR RECONSIDERATION OF VEHICULAR RADAR BANDS

SUMMARY

Following are comments of Honda R&D, Ltd. and Honda R&D North America, Inc. to the notice issued by the FCC on November 8, 1994 regarding the allotment of millimeter wave bandwidths.

Honda has no objection to the radar bands proposed by the FCC for automotive applications; however, we hereby specifically request that the 60-61 GHz bandwidths be included as one of the vehicular radar bands.

Although the issue of interference with NOAA's systems was addressed by the FCC, we do not envision any interference problems occurring as a result of including the 60-61 GHz bandwidth. Regarding transmitting output, we agree with the power density specified by the FCC under their "Unlicensed Vehicular Bands."

EVALUATIONS OF RADIO INTERFERENCE

According to the CCIR report (CCIR Rep. 719-3, Report of the CCIR, Annex to V, 1990), the amount of signal attenuation in the 60-61GHz bandwidth caused by oxygen molecules at <u>land surface</u> is at its greatest, approximately 1.6 dB/100 m compared with the level of 0-0.1 dB/100 m with other frequencies. This means, therefore, that the possibility of interference and crosstalk is at its minimum for vehicular radars at the frequencies of 60-61 GHz.

If you calculate the signal attenuation from land surface to satellite zenith direction it will be approximately 150 dB to 200 dB assuming the amount of oxygen molecules in the atmosphere from ground level to the satellite's orbiting altitude. The signal attenuation level at this height above ground level is so great that interference with the NOAA's satellite should not occur.

HONDA'S CURRENT RADAR TECHNOLOGY

Honda has recently completed a study entitled, "Two-dimensional Millimeter-Wave Radar for Automobiles under the Time Sharing Multibeam Method," using 60 GHz.

The result of this study will be made public in March as a presentation at the annual meeting of "1995 ITS AMERICA."

We hereby attach a preliminary copy of our presentation, as supplementary information.

For vehicular radars to be effective, it is important to be able to seek and identify the position of obstacles ahead (coordinates). We believe, therefore, it is very important for the sake of safety and effectiveness to be able to implement this technology with a high degree of accuracy to anticipate and predict collisions.

This radar is the type that can detect with a high degree of accuracy, obstacles up to 100 m ahead with a distance accuracy of within 50 cm by using a CW method of FM-CW. Such a highly accurate radar is the result of our ability to develop an FM modulator with good linearity at 60 GHz.

This FM modulator is the most crucial core technology determining distance accuracy.

Though it is very difficult to develop technology to implement electronic scanning at millimeter-wave bands, we were able to achieve this at the 60 GHz bandwidth with two-dimensional vehicular radars.

This method is "the Time Sharing Multibeam Method" described in the attached paper, where changes are made with a switch. By combining signal processing with this method, we were able to pinpoint obstacles 100 m ahead within a directional accuracy of 1 m, laterally.

OUR REQUESTS

1. We respectfully request that the FCC add 60-61 GHz as vehicular radar frequencies.

2. As for transmitting output, we agree with the FCC proposal as set forth under "Unlicensed Vehicular Radar Bands."

3. We would like to request 1 GHz as the bandwidth. This is with the consideration that frequency stability is impacted by modulation width and temperature properties of the device.

CONCLUSIONS

We were able to implement highly accurate vehicular radars at the frequency of 60 GHz as the attached material describes. By selecting the 60 GHz bandwidth, there is the possibility of reducing radio interference more than at any other frequencies. Thus, by using this frequency along with other systems in the future, we can make common use of parts, and thus reduce costs considerably. As indicated in our comments, Honda has already completed the development of a highly efficient vehicular radar using the 60 GHz bandwidth and are looking forward to implementing it in the United States. We are confident that allowing the use of this bandwidth will provide Honda a greater chance to contribute to the American society and ITS development in the United States through its technology.

HONDA R&D, Ltd.

A STUDY ON TWO-DIMENSIONAL MILLIMETER-WAVE RADAR FOR AUTOMOBILES UNDER THE TIME SHARING MULTIBEAM METHOD

1.ABSTRACT

Since sometime in the 1970s, difficulties brought about by automobiles such as increasing accidents, atmospheric pollution, and depletion of energy at the cost of their convenience have been discussed as social problems. Under these circumstances, projects are planned and promoted in advanced road-using countries to solve the problems to be tackled to simultaneously improve safety, reduce congestion, and also to reduce ill effects on the environment by making roads and automobiles intelligent. IVHS in the present report is also ranked as an important project.

This paper deals with the operation support system technology for AVCS etc. It particularly concentrates on radar technology as a necessary component to materialize the advanced ability to recognize and discriminate the external environment, while presenting the techniques using the time sharing multibeam millimeter wave radar developed by us.

2. INTRODUCTION

In a mixed-traffic society as we are in, it is necessary not only to ensure the safety of drivers themselves but ensure the safety of mixed traffic. However careful each driver is in mixed traffic, accidents do occur with "a certain probability." This is because advances in mechanical engineering have brought the speed of automobiles some dozen times higher than that of human beings, or beyond the ability of human instincts to avoid danger. Under these circumstances, it is necessary to establish a traffic system that enables traffic elements to avoid collisions autonomously and provide a means for instantaneously transmitting the wish to act to others.

Fig. 1 shows the configuration of the driving support system forming IVHS. As shown here, the driving support system supports and automates all or part of the steps: recognition and decision and operation necessary for the driver's driving operation by detecting the external driving environment with the help of sensors, computers, actuators and communications systems at both vehicle and infrastructure sides. The external environment of driving denotes a wide range of external environments as viewed from the vehicle including such factors as other vehicles nearby, road configuration, condition of road surfaces, weather and drivers. Although the detection of external driving environment is related to the essence of driving, it is the part for which we have relied on human perceptions. Thus, in IVHS, it is also important to realize external sensing techniques that go beyond human perception. One of such external sensing techniques is radar of automobiles. Main possible applications of radar include supplementing the driver's visual information and giving an alarm in the event of danger (rear hit alarm system) and controlling the vehicle with radar information to increase safety (vehicle-to-vehicle distance control system). Table 1 shows the radar systems that are possible at support levels.

3. RADAR ENGINEERING

3-1 Features of Sensors and Current Radio Wave Radars

For a long time, studies have been made on systems for preventing accidents with alarms in dangerous driving situations, while monitoring the surroundings of the vehicle with external sensors. Table 2 shows typical external sensors and their features.

For laser radar using light, systems with a high-accuracy detecting capacity have been developed through rapid technological innovation, but they have the drawback of being vulnerable to weather.

"Radio-wave radar" developed in the areas of military demand have a high detecting capacity in bad weather (rain, mist, dust, etc.), but its practical use has been delayed by engineering barriers in mass-producing high-frequency devices and compacting antennas. Recently however, trends have been emerging toward using millimeter wave bands for automobile radar in the United States, Europe and in Japan. Europe has already determined a frequency range: 76 - 77 GHz and Japan is planning to use 60 GHz bands. Table 3 shows wave specifications and systems of automobile radar in Europe and Japan.

3-2 System Requirements of Radar

To know the likelihood of a car colliding, it is necessary to develop a radar system designed to detect at what locations, in front, beside or at the rear, there are obstacles and how fast and in what direction they are moving as shown in Fig. 2.

Requirements for such radar systems differ with decelerating capacity to stop the vehicles and the limit of vehicle velocity taken into account. Fig. 3 shows the stopping distance of a vehicle running at velocity V and then braked at decelerating rate α. The detection distance needed for a vehicle to be stopped without colliding with obstacles must be above the stopping distance here plus the time lag needed for the driver to operate the brakes.

If an obstacle is moving, its velocity must also be detected accurately. The relative velocity can be obtained by differentiating the distance. Here a very high distance accuracy is required.

For a driver to know if his or her car will ultimately collide with an obstacle, information on the lateral location of the obstacle is also needed. Furthermore, automobile radar can operate erroneously due to reflections from guard rails or a failure to detect a target when the vehicle is traveling through a corner. The solution to such difficulties is beam scanning. There are several methods of beam scanning for automobile radar: (1) With continuous mechanical scanning with an antenna beam, discrimination is made between targets and unnecessary reflecting objects from azimuth information and reflected radar signals. (2) A multi-beam system that shifts several antenna beams. (3) A beam-steering system that directs the antenna in the traveling direction when the vehicle is in a corner.

A part from these beam scanning techniques, there is a range cut system that reduces the maximum detection range when the vehicle is in a corner.

4. TWO-DIMENSIONAL MILLIMETER-WAVE RADAR UNDER A TIME-SHARING MULTIBEAM METHOD FOR AUTOMOBILES

Considering that the primary purpose of automobile radar is to supplement the human visual sense, we understood that millimeter-wave radar which exhibits excellent properties in unfavorable environments was optimal:

To make the system more intelligent and more reliable than the conventional single-beam radar, a time-sharing multibeam method that shifts beams electrically was selected. To improve azimuthal accuracy, amplitude-angle conversion which is one of the monopolize radar systems was employed. The detection distances required for radar were determined from the stopping distances in Fig. 3. For the necessary distance accuracy, it was decided to employ a technique that calculates relative velocity by differentiating distance data.

Fig. 4 conceptually illustrates the two-dimensional millimeter wave automobile radar under the time-sharing multibeam method.

4-1 FFT Calculation of Distance Data and Configuration of Time-sharing Multibeam

The radar system developed by us uses an FM-CW method to measure the distance to the obstacle and calculates the required detection distances by FFT processing. Using FFT processing enables multitargets to be detected, which is difficult under the conventional FM-CW method. Fig. 5 shows calculations for detecting distances.

When trying to realize a two-dimensional radar, an important problem is to compose a multibeam with mounting on vehicles taken into account. Fig. 6 shows an outline of the configuration of a time-sharing multibeam. Fig. 7 shows a time chart for producing a time-sharing multibeam.

4-2 Principles of Amplitude-angle Conversion and Two-dimensional Radar Mapping

An amplitude-angle conversion requires at least two beams. The principles are shown in Fig. 8, Fig. 8 (a) shows two beams detecting targets. Suppose that input power A is detected at CH1 and input power B at CH2, as shown in Fig. 8 (b). Then calculate the difference A - B and the sum A + B and obtain the ratio (A - B)/(A + B). From this ratio, the angle between the center line of each beam and the target concerned can be obtained. Fig. 8 (C) shows the relation between ratio (A - B)/(A + B) and angle θ between the target and the beam center line.

Preparing a two-dimensional radar map consisting of polar coordinates as shown in Fig. 9 requires a time-sharing multichannel radar system consisting of several channels of the FM-CW radar, described earlier, arrayed in the azimuthal direction.

First, the beat signals that are the output signals of the channels are input into the FFT frequency, analysis to calculate spectrum data. The spectrum data of the frequency components corresponds to the distance coordinates, and is arrayed from low frequency at the origin of the coordinates to high. The channel numbers correspond to the azimuthal coordinates and the spectrum data of the channels are arrayed in the order of the azimuthal direction in scanning.

To increase the calculating accuracy of the azimuthal coordinates for the frequency spectra arrayed on the polar coordinates, the amplitude-angle conversion principles explained in Fig. 8 were employed. This processing enables an azimuthal resolution above the number of the channels to be obtained for the azimuthal coordinates of objects.

Using the spectrum data array obtained by the procedure above, a two-dimensional radar map can be prepared and represented in PPI.

4-3 Performance Evaluation

Distance accuracy and lateral accuracy necessary for two-dimensional radar were measured. The results are as follows:

A corner reflector having a comparable reflection cross-section with a smaller car was used as a target and distance accuracy was measured. Fig. 10 shows the results with a detection distance of 100 m. Here, the distance accuracy is within about 50 cm, showing that it is a very high-accuracy radar system.

It was already known that distance accuracy under an FM-CW system is determined by the properties of the FM oscillator. We attained the high distance accuracy shown in the figure using a high-performance FM oscillator. This also showed that the relative velocity could be calculated satisfactorily by differentiating distance accuracy.

The corner reflector mentioned above was placed at a distance of 100 m and then laterally moved at 1 m intervals within a range of $\pm$ 5m. The results of measurements are shown in Fig. 11. Evidently, the lateral accuracy is within about 1 m. This also shows that the system is also a high-accuracy model of two-dimensional radar.

All this proved that the "time-sharing multibeam rader" we developed had a higher accuracy than conventional millimeter wave rader.

5. CONCLUSION

The current automobile traffic system, has such poor information communication between its elements that safety there relies on the sensory functions of drivers. Under such circumstances, it is desirable to carry out IVHS projects promptly and develop them further. It is observed in particular that supplementing the sensory functions of drivers and making a practical "automobile radar" beyond human sensory perception are essential to IVHS projects. As IVHS projects proceed, the "millimeter wave radar" presented here is expected to be satisfactorily effective. To promote the spread of this millimeter wave radar, its engineering must be changed from conventional concentrated applications in military areas to the private sector. It also seems necessary to actively utilize the MMIC technology recently studied enthusiastically.

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